

Tracking and Ground Based Navigation: Performance of Hydrogen Maser Cavity Tuning Servo

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An experimental automatic cavity tuner has been demonstrated with the atomic hydrogen maser frequency standards developed by the Jet Propulsion Laboratory. The ability of this tuner to prevent RF cavity frequency drift in the maser is shown, and the methods used to modulate hydrogen transition line width in the maser during tuner operation are compared.

I. Introduction

The long-term frequency stability of a hydrogen maser atomic frequency standard is primarily determined by the stability of the microwave cavity resonant frequency. Temperature controller drift, mechanical vibration, power outages during maintenance periods, etc., cause cavity frequency displacements which will pull the maser output frequency if not periodically corrected. The maser output frequency is pulled by the cavity resonant frequency by the ratio of hydrogen transition line width to microwave cavity bandwidth.

An experimental autotuner (automatic cavity tuner) has been developed at JPL which removes long-term RF cavity drift. This unit increments hydrogen transition line width and servos the cavity frequency such that this increment in line width does not measurably change

maser output frequency. A more detailed description of the autotuner can be found in Refs. 1 and 2.

A reference frequency standard is required to enable the autotuner to make difference measurements of maser output frequency at the two different hydrogen transition line widths. Since only a relative frequency difference measurement is needed, absolute frequency calibration of this reference standard is not important.

II. Performance

The performance of the experimental autotuner has been demonstrated at Goldstone with the two JPL hydrogen masers. The response of the autotuner to a specific cavity frequency offset has been measured, and the data are summarized in Fig. 1. The vertical axis represents fractional maser offset frequency (caused by pulling from

an offset cavity frequency), and the horizontal axis represents elapsed running time of the autotuner. For each type of reference standard, the maser cavity was purposely retuned away from the hydrogen transition frequency so as to pull the maser output frequency 2.7 parts in 10^{12} . Then the autotuner was turned on and allowed to servo the cavity frequency and reduce maser offset frequency to some limiting value as determined by the frequency stability characteristics of the reference oscillator. The ultimate tuning accuracy achieved by the autotuner and the elapsed time required to reach this accuracy are labeled in the figure for both types of reference standards. Using a second hydrogen maser as a reference, the autotuner maintained maser offset frequency to less than 1 part in 10^{14} after 2½ hours. A rubidium frequency standard, when compared with a hydrogen maser, has approximately two orders of magnitude less frequency stability for measurement times of 100 seconds; therefore, autotuner integration times must be longer when this type of standard is used as a reference oscillator. When using a Hewlett-Packard Model 5065A Rb standard, the autotuner required 15 hours to reduce and hold maser offset frequency to within 7.5 parts in 10^{14} .

It should be noted that the data in Fig. 1 do not represent an attempt to achieve an optimum tradeoff between response time and ultimate tuning accuracy. Therefore, it is expected that a selection of different autotuner servo parameters will result in improved tuning accuracy in

the case of the rubidium reference standard, at the expense of slower response times.

III. Transition Line Width Modulation

There are three methods used to periodically vary hydrogen transition line width in the JPL hydrogen masers during autotuner operation. These are:

- (1) Vary the RF power to the hydrogen dissociator.
- (2) Vary the flow rate of hydrogen gas into the maser system.
- (3) Modulate the cross-sectional area of the atomic hydrogen beam in the maser with the use of a mechanical shutter.

During the autotuner performance tests at Goldstone, it was found that both methods (1) and (2) generated thermal transients in the maser which adversely affected cavity resonant frequency stability. The end result was that when the autotuner was turned off, the maser frequency would commence to drift many parts in 10^{14} from the previous "tuned" value. As a solution to this problem, a mechanical hydrogen beam chopper has been designed and fabricated which is not expected to disturb magnetic or thermal conditions in the maser sufficiently to affect maser frequency stability. This unit will be described in a future article.

References

1. Finnie, C., "Frequency Generation and Control: Atomic Hydrogen Frequency Standard," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. I, pp. 73-75. Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1971.
2. Finnie, C., "Design of Hydrogen Maser Cavity Tuning Servo," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. II, pp. 86-88. Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1971.

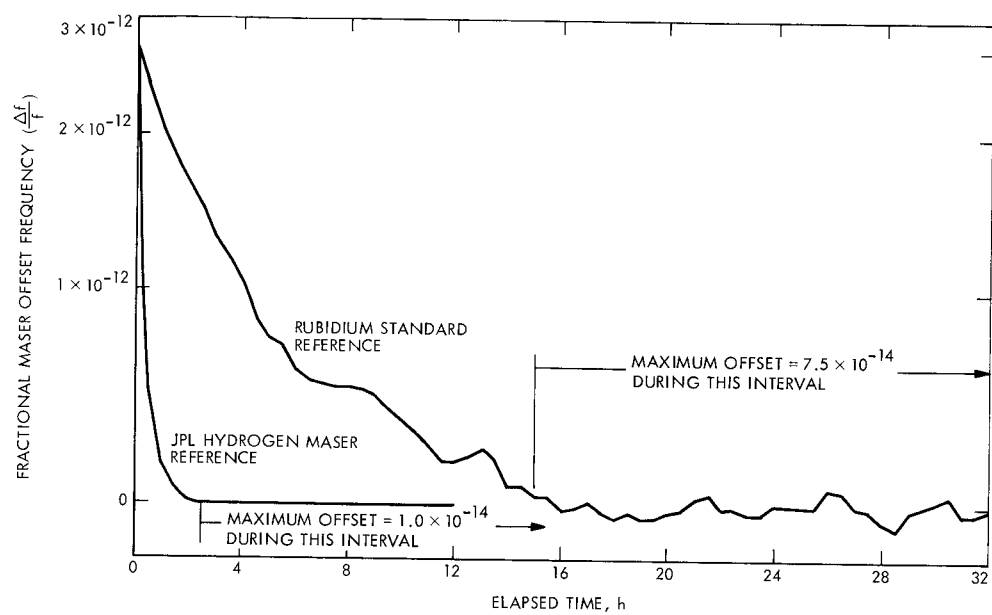


Fig. 1. Response time and tuning accuracy of automatic cavity tuner